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CONTENTS

The Dependence of Binocular Fusion on Timing of Peripheral Stimuli and on Central Process. 3. Cortical Flicker: C. H. BAKER 151

The Clinical Application of the Verdun Projective Battery: HEINZ LEHMANN and HERBERT DÖRKEN, JR. 164

Effect of Length of Series upon Generalization and Central Tendency in the Discrimination of a Series of Stimuli: B. R. PHILIP 173

Some Emotional Problems of Orphanage Children: MARGARET STEVENSON 179

Studies in Somesthesis. III. Role of Somatic Areas I and II in the Acquisition of Roughness Discrimination in the Rat: JOHN P. ZUBEK 183

Books Received 194

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Canadian Journal of Psychology

THE DEPENDENCE OF BINOCULAR FUSION ON TIMING OF PERIPHERAL STIMULI AND ON CENTRAL PROCESS

3. Cortical Flicker[1]

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Defence Research Board, Toronto

THE CONCEPT of neural summation has been found valuable in describing several neural effects which have been demonstrated in the optical system. Thus Adrian and Matthews (1, 2) found in studies of the eye of the eel that stimulation of four small retinal areas so placed as to be at the corners of a square, results in a shorter latency of the optic nerve discharge than when only one point is stimulated. Graham (11), in studying the Limulus eye, which is composed only of receptors and their discrete fibres (there are no interconnecting pathways as there are in the human retina), found that regardless of how many receptors were stimulated the latency of the optic nerve response remained constant. The absence of neural interaction is, in this case, to be expected.

Granit (12) used the critical flicker frequency as an index of interaction in studying human retinal interaction effects. Critical flicker frequency is a function of intensity and so a rise in frequency was assumed to be the result of increased stimulus intensity. He found, using a stimulus pattern similar to that employed by Adrian and Matthews, that in the peripheral retina critical flicker frequency was about 2.5 cycles per second higher for all four stimulus areas together than for any one of them alone.

Graham and Granit showed, too, that retinal summation occurs when one portion of the retina is constantly stimulated, with another receiving intermittent stimulation. Summation in this case was calculated to be 4.6 per cent. Fry and Bartley (10) performed similar experiments which show that both summation and inhibition occur in the retina.

Granit and Davis (13) demonstrated temporal retinal summation by stimulating different retinal areas within certain brief time intervals by using subliminal stimulus intensities. They found that two stimulus flashes, each of subliminal intensity, will be perceived, providing the time interval between them is sufficiently short.

The above references have been employed to point up the fact that neural summation is definitely a property of the visual receptor system.

[1]This is the concluding article in a series which has appeared in the three preceding issues of the *Journal*.

Can summation be shown to occur farther back along the optic pathways? Present evidence suggests that it can. Lythgoe and Phillips (16) measured changes in brightness threshold during dark adaptation in right, left, and both eyes. They found the binocular threshold to be lower than the monocular. Thompson (25) showed that the degree of pupil constriction which results from monocular visual stimulation is significantly less than that obtained when both eyes are stimulated.

Summation effects having been demonstrated within the retina and within the neural pathways, then, it is not inconceivable that they should occur in the visual cortex. Bartley (7) said, ". . . denial of interaction, at least in the cortex, is impossible. There seems to be a need for integration somewhere to account for the unity of experience," in discussing the retinal mosaic pattern of receptors.

Aim of Present Study

Alliance and antagonism having been demonstrated in the previous parts of this series (3, 4, 5; see also 6), it was the purpose of the experiments outlined in this part to attempt to determine the approximate neural locus of such interaction.

With reference to Figure 1, it can be seen that when the two retinas are stimulated with synchronous intermittent stimuli the two occipital lobes experience synchronous periods of excitation and quiescence. However, when the retinas are stimulated alternately the lobes are never quiescent but are in a state of excitation at all times. In order for fusion to occur under synchronous conditions, then, occipital lobe excitation must be sufficient to bridge the experiential gap between non-excitation and sufficient-excitation-for-fusion. Under alternate conditions the gap to be bridged is smaller, that is, between *some*-excitation and sufficient-excitation-for-fusion: a summation effect.

The hypothesis for this section, therefore, is that flicker-fusion frequency is lower under alternate modes of stimulation because the summation of occipital lobe excitation need not be so great to permit the experience of fusion as it must be under synchronous modes of stimulation.

If this hypothesis is true, then it must be demonstrable when a single lobe only is activated—Experiment 10. Similarly, it will be demonstrable when both lobes are activated by neural discharges arising from stimulation of the lateral halves of a single retina—Experiment 11.

Experiment 10

The stimulus sources in this experiment were the two upper neon ("instantaneous") apertures which subtended a visual angle of 53

minutes. Each aperture was more than half occluded (the right half) by a black face being placed over the apertures to cover slightly the aperture centres. Directly over the aperture centres pinholes were made in the two faces. The distance between the pinholes and the vertical edges of the occluding faces subtended a visual angle of eight minutes. Each

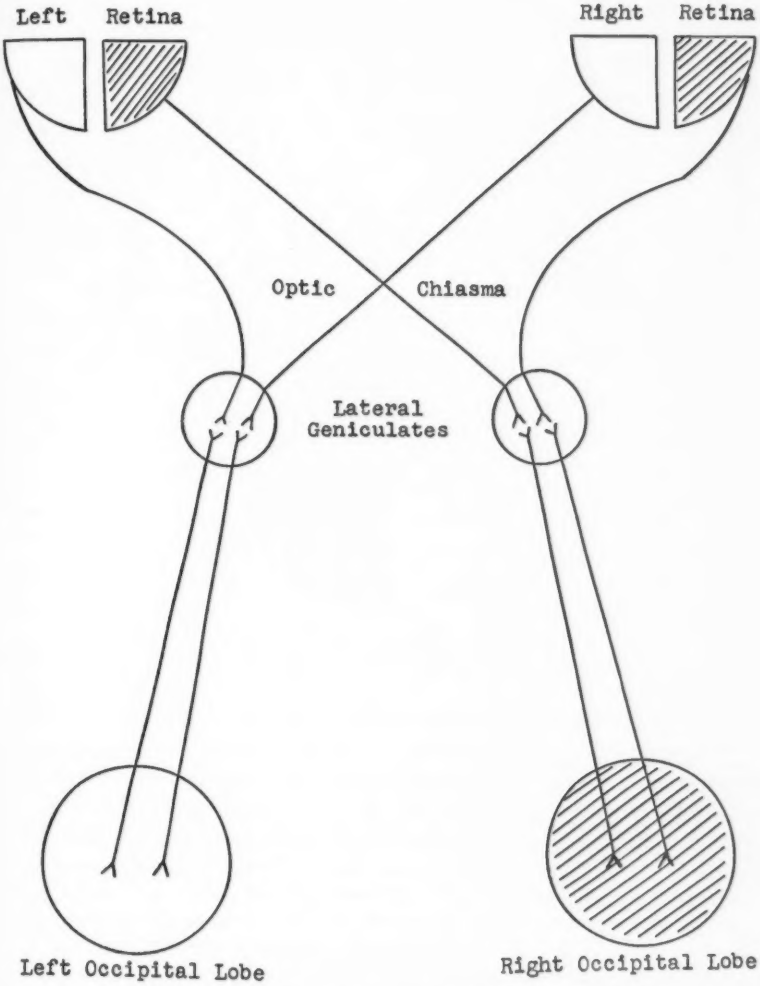

FIGURE 1. Showing the gross anatomy of the optic neural apparatus.

aperture portion illuminated was bisected, one horizontally and the other vertically, by a thin hair line. In binocular combination the apertures appeared as a single, almost semicircular figure, with its straight edge vertical and to the right, and divided into four sections by thin hair lines. In close proximity to the straight edge appeared a pinpoint of light (Figure 2).

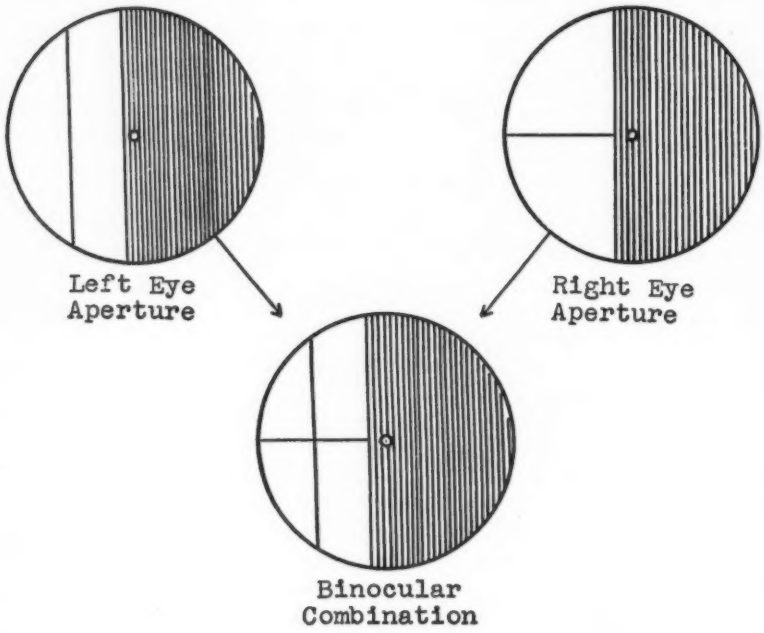

FIGURE 2. Showing the arrangement of the stimuli sources for Experiment 10.

The pinpoint aperture served as a fixation point. With the pinpoint fixated, neural impulses initiated at these two retinal areas travelled to the right occipital lobe only (Figure 1). (Anatomical justification for this procedure is given by Lyle (15), who states: "Recent workers have come to the conclusion that the macular fibres are split or bisected and decussate at the chiasm, the lateral half with the nasal half of the other eye, and their cortical representation is formed from the right half of both macula at the right occipital pole and from the left half of both macula at the left occipital pole".)

With the eyes fixating the pinpoints, six readings were taken for both

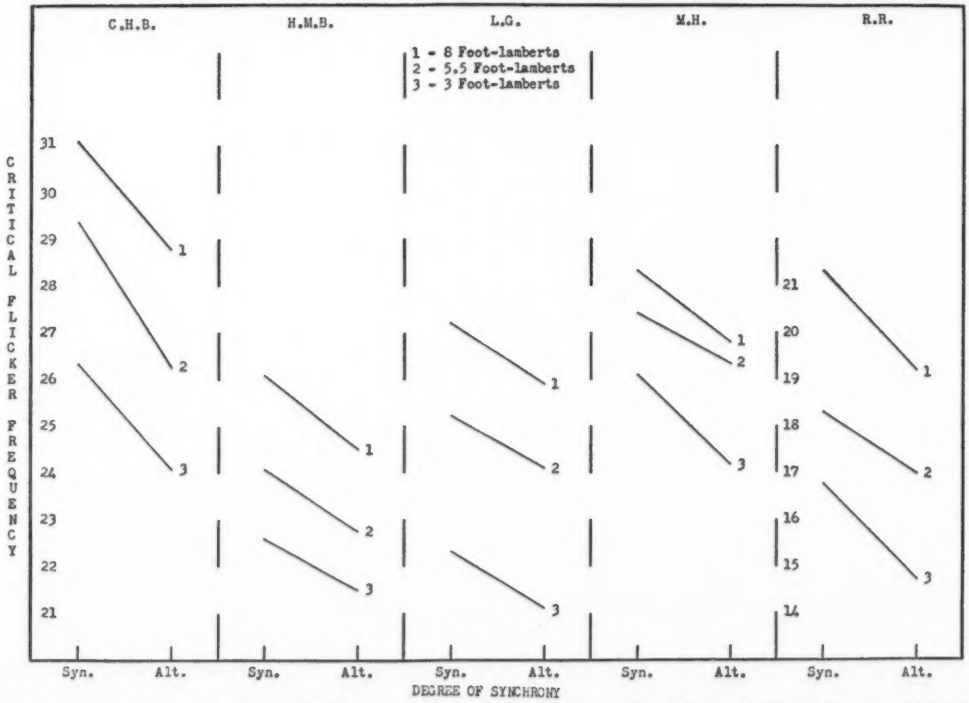

FIGURE 3. Showing the critical flicker frequencies resulting from stimulation of the right occipital lobes of five subjects, for the synchronous and alternate conditions at each of three brightness levels.

the synchronous and alternate conditions of stimulation at each of the three brightness levels.

Results

The results of Experiment 10 are graphically shown in Figure 3.

All differences between the synchronous and alternate modes of stimulation have been statistically tested and found to be significant. (All 15 differences are significant at the .001 level of probability.)

Conclusion

By binocular stimulation of the right halves of the two foveas (and hence the right occipital lobe only) evidence was gained to support the hypothesis that critical flicker-fusion frequency is the result of neural summation effects in the occipital cortex.

Experiment 11

This experiment was concerned with activating both occipital lobes through intermittent stimulation of a single retina.

The stimuli sources employed were again of an "instantaneous" nature. A single circular aperture subtending a visual angle of one degree and 75 minutes was punched in a black cardboard face so as to have its centre directly over the narrow partition dividing the two top chambers of the apparatus light box. The space between the face and the dividing partition was tightly sealed so that light from one box could not enter the other. Milk-glass slides were attached to cover the backs of the two semicircles so produced. A quarter-inch strip of black paper was placed on the vertical edge of the dividing partition. At the aperture centre a single pinhole was punched in the narrow strip so as to admit light from both light chambers (Figure 4).

When the top neon lights were illuminated, the aperture appeared as a single circle of brightness with a broad vertical diameter line. In the

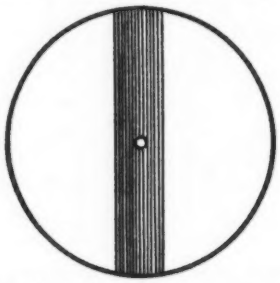

Figure 4. Showing the single aperture arrangement of the stimulus source for Experiment 11.

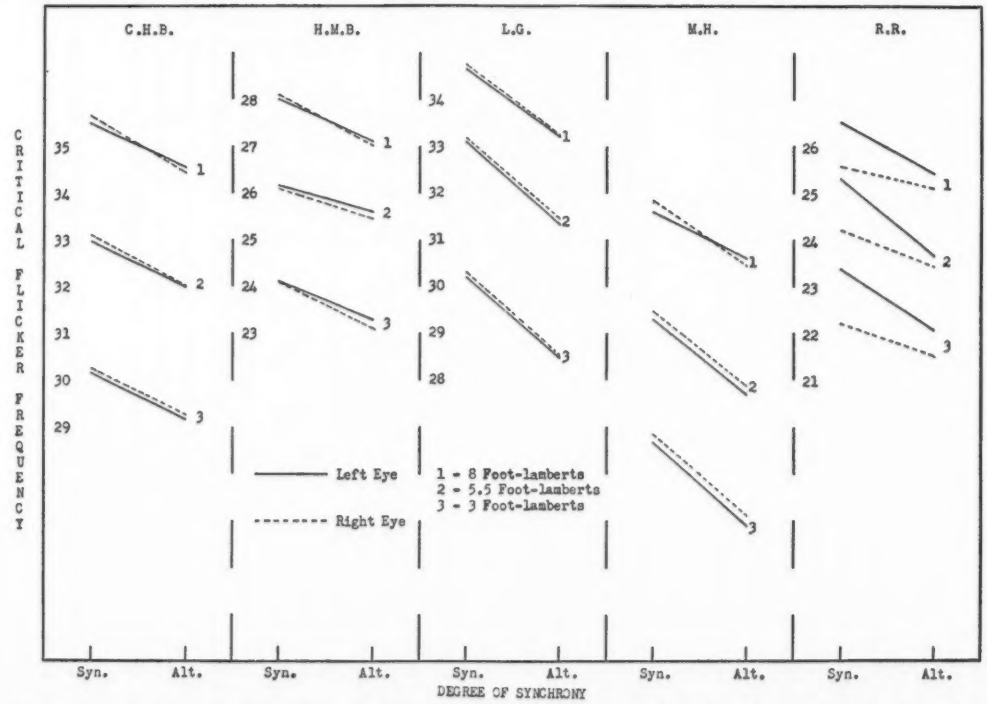

FIGURE 5. Showing the monocular synchronous and alternate critical flicker frequencies resulting from stimulation of both occipital lobes, for each eye of five subjects at each of three brightness levels.

centre of the diameter line a pinpoint of light was apparent. With the apparatus commutators synchronously timed, the complete circle was successively illuminated and occluded. Alternate timing presented one semicircle and then the other in an alternate fashion.

With the eyes fixating the pinpoint, six readings were taken, for each eye singly, under both the synchronous and alternate conditions. Again three brightness levels were employed. The septum was not used but subjects still regarded the stimulus source through the flexible prisms.

The apparatus being so arranged, it was possible, when fixating the pinpoint of light, to stimulate the right and left halves of a single foveal region under synchronous and alternate conditions. Such monocular stimulation directed neural impulses to both occipital lobes (Figure 1).

Results

The results of Experiment 11 are graphically shown in Figure 5.

All differences between the critical frequencies yielded by the synchronous and alternate conditions of stimulation have been statistically tested and found to be significant. (Three differences are significant at the .01 level of probability, and 27 at the .001 level.)

Conclusion

By binocular stimulation of the lateral halves of a single foveal region (and hence both occipital lobes) evidence was gained to support the hypothesis that critical flicker-fusion frequency is the result of neural summation effects in the occipital cortex.

Discussion (Part 3)

The two experiments outlined in this part were conducted to test the hypothesis that critical fusion frequency is the result of neural summation effects in the occipital cortex. Alternate intermittent stimulation of the foveas need not be as frequent, to permit fusion, as synchronous stimulation, because neural summation need not be so great in the occipital centres subserving visual experience.

But the synchronous stimulation of the two halves of a single fovea (Experiment 11) is identical with the monocular modes of stimulation employed in experiments outlined in Part 1 (3, 4). In this case one finds that the synchronous condition does *not* result in higher, and the alternate condition in lower frequencies than the monocular, as in the case of experiments outlined in Part 1. But rather the monocular and synchronous conditions yield identical frequencies (because the con-

ditions themselves are, in effect, identical) which are higher than the alternate. Alliance under such equivalent conditions is not demonstrated. And the fact that Part 1 experiments have shown that alternate modes of binocular stimulation result in lower frequencies than the monocular mode can also be explained on the basis of an allied or summating effect.

The concept of antagonism is not needed to explain different binocular flicker-fusion frequencies due to differential timing of visual stimuli so long as those stimuli are symmetrical in nature. An antagonistic form of neural interaction in the optical system is demonstrable only when the neural impulses initiated at the two retinas are asymmetrical in nature, as shown in Part 2 (5).

Conclusion (Part 3)

These experiments sustain the hypothesis that the critical fusion frequency of intermittent stimulation of foveal areas is the result of a critical degree of excitation of the cortical centres subserving visual experience. This excitation is the end-product of summating neural impulses arising from one or both foveas. Such neural impulses are never antagonistic so long as the visual stimuli employed are symmetrical in nature, regardless of the degree of synchrony of stimulus-timing conditions.

General Discussion

This investigation was undertaken to determine, if possible, the nature of the fusion of monocular components initiated by relatively simple objects of regard in the vision field (3, 4, 5, 6). The question is ultimately concerned with the manner in which corresponding retinal points (points having the same locality reference) have the same cortical reference.

That stimulation of corresponding retinal points results in singleness of binocular vision has often been regarded as evidence of an anatomical union of the neural apparatus proceeding to such retinal points. Wollaston (27) and Newton (20) presumed that this union was at the chiasma. Sherrington (24) cites Rohault and Muller as believing corresponding points to be served by twin fibres "from one and the same ganglion cell in the cerebral substance." Aubert believed in "a single common centre or point of the sensorium." McDougall (18), in 1901, performed a simple experiment which implied a similar arrangement. He exposed the right eye only to a bright light for 30 seconds and then

occluded all light from his retinas. When the positive after-image had disappeared a small amount of light was allowed to pass through the closed lid of the left eye for two seconds. This revived the after-image for five seconds.

Most investigators are of a similar belief. For instance, this view (or a modification) is subscribed to by Morgan (19), Verhoeff (26), Bartley (8), Henschen (14), Marshall and Talbot (17), Zoethout (28), Penfield (22), and Polyak (23). But to date the final anatomical proof has been lacking.

But Sherrington, from his experiments in this field, has denied that such can be the case. He says (24): "Were there to exist such a common mechanism situate as a unit at conjunction of the two convergent systems and were phases of excitement timed so as to fill pauses between excitations transmitted from the other, then there should be evidence of this in the time-relations of the phenomena induced. The state of excitement should tend to be maintained across periods that would otherwise checker it as pauses." At the same time he admitted that "the cerebral seats of right-eye and left-eye visual images" were "no doubt interconnected by conductive paths." Paradoxically, he refused to attribute any sensory significance to this fact, even though his Section II experiments with asymmetrical flicker gave results which "might be interpreted as the outcome of community of the physiological mechanisms attaching to the 'paired retinal points.'"

Verhoeff (26) pointed out, too, that Sherrington must assume that flicker is abolished in the brain at the same rate at which it is abolished in the retina. That this is not the case was indicated earlier (3).

Furthermore, a repetition of some of Sherrington's experiments indicates that his results were in error. Not only were greater differences found between synchronous and alternate modes of foveal stimulation (an average difference of 2.4 cycles per second versus one of 4.6 cycles per second) but these greater differences are found to be statistically highly significant. Admittedly, Sherrington had no statistical tools for determining the reality of differences, but it is difficult to see how his obtained differences were so small. Presumably they were due to some artifact of his apparatus, but the truth of this presumption can probably never be determined.

That some form of anatomical communion of the neural fibres which proceed to corresponding retinal points is accepted by many authorities has already been pointed out. But the present experimental results indicate the danger of accepting a simple literal explanation such as that offered by Zoethout (28), who says: "It is best to assume that each sensitive element in one retina is neurally connected with a definite

discrete cortical receptor, and that the corresponding point in the other retina also makes connection with this same cortical point."

Per contra, the evidence gained from these experiments indicates that binocular fusion is equally possible whether the retinal areas stimulated are of a corresponding nature *or not*. In harmony with this conclusion is the known fact that objects lying a short distance to either side of the horopter can, too, be seen as single. It is usually stated, then, that corresponding retinal points are surrounded by small areas which, too, when stimulated, give rise to single vision (28). Panum's areas, as they are called, are named after the investigator who inferred their existence.

Peckham (21) reports that he was able to demonstrate binocular fusion in 100 subjects when "errors" in fixation of as great as 10 degrees on opposite sides of the fovea could occur. He believes that the theory of anatomically corresponding points must be modified or rejected in explaining such phenomena as binocular fusion, diplopia, and stereopsis, in favour of an empirical theory of functional correspondence.

Further evidence which attempts to prevent too rigid a conception of the symmetrical alignment of corresponding points is offered by clinical cases of squint in which subjects develop single binocular vision notwithstanding the deviating eye (9, 28). In such cases a non-foveal retinal area acquires a correspondence with the fovea of the normal eye.

Indeed, the wealth of available evidence implies a vicariously functioning neuroanatomical arrangement of the cortical visual apparatus involved in fusing monocular images, which Sherrington failed to consider. Finding that the rigid point-to-point neuroanatomical concept did not explain his results, he appealed to psychology for the answer.

General Conclusions

1. Binocular fusion involves a central process which is active in combining and integrating the neural impulses arising from stimulation of corresponding retinal areas.

2. Within certain limits these areas need not be in a geometrically corresponding relation to one another to permit fusion.

3. Similar retinal images, or symmetrical forms of flickering stimuli, initiate neural impulses at the two retinas which reinforce one another in sensation, regardless of their temporal synchrony of stimulation. Only when retinal images differ, or flicker is asymmetrical, are the initiated neural impulses antagonistic to one another.

4. The central process is a summatory one by means of which neural impulses arriving at the cortex along a final common path excite cortical neural regions, and the summated energy of such excitation directly determines the degree of sensation.

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THE CLINICAL APPLICATION OF THE VERDUN PROJECTIVE BATTERY

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THE TREND to increasing use of projective psychological tests has brought with it an increase in the number of such tests. The methods of scoring and interpretation applied to these test procedures are often of considerable complexity and certainly do not always exclude the possibility of the examiner's personal bias colouring the results.

In view of the ever-growing importance of psychological test data for the evaluation of psychiatric patients, a need has arisen for the clinician to have at his disposal some tests of personality which require a minimum of instruction and practice on the part of the examiner, yet give reliable results.

The "percentile standardization of several brief projective techniques" reported here has been designed in an endeavour to adapt some widely used "projective tests," with their inherent advantages, to a series of simple procedures that are brief, readily administered, and capable of rigidly objective scoring by personnel with limited training in psychometrics. Also, these tests have been specifically adapted for the evaluation of psychotic conditions, where simplicity is requisite, since a limited span of attention typifies many of these disorders.

Rather than explore the possibilities of new and unproven techniques, it was decided to modify well-established tests whose extensive use and literature leave little doubt of their efficacy. Our principal aim was the development of a test procedure which would readily provide the clinician with a means of obtaining test data for corroboration of clinical impressions by objective test scores and for re-evaluation or follow-up.

The tests selected for experimentation were: (1) a timed 10-word Word Association Test; (2) a 10-word association test, selected from the frequency tables of Kent and Rosanoff (not timed) (2, 5) to act as a Conformity Index; (3) Harrower's Multiple-Choice Rorschach Test, series A (1); and (4) pictures 5, 14, and 11 of Murray's Thematic Apperception Test (6, 7). These tests were not used, initially, as a battery: data were accumulated on each test more or less independently until there was sufficient material to permit us to establish a quantifiable scoring system.

[1]The authors wish to express their appreciation for the co-operation of Dr. George E. Reed, Medical Superintendent of the Verdun Protestant Hospital; and are particularly indebted to members of the psychiatric staff who aided in the administration of a considerable portion of the test records.

For the final standardization groups, the tests were used as a battery and given to an entirely new population. A total of 1,393 subjects, 580 "normals" and 813 "abnormals," were examined in order to establish the percentile standardization. These data were accumulated over an eight-year period. The percentile standardization,[2] technique of administration, and method of scoring the tests which comprise the "Verdun Projective Battery" are described in detail in a mimeographed test manual available on request from the authors (3).

The present paper will attempt to present some of the more outstanding interpretative features as they have become apparent through clinical application. Only the grosser differences among diagnostic groups will be discussed, mainly in areas where some statistical substantiation can be offered.

The Diagnostic Categories

In Table I, the percentage of cases falling within the score ranges established are seen to vary according to the diagnosis.

TABLE I

Percentage of Cases of Given Diagnosis in Each of the Three Score Ranges
(Final Standardization Groups)

Interpretation	Score Range		
	0–6 Within normal limits	7–11 Possible psychopathology	12–45 Definitely abnormal
"Normal" N = 100	83.0	14.0	3.0
Mania N = 44	34.1	22.7	43.2
Schizophrenia N = 109	11.9	19.3	68.8
Depression* N = 43	11.6	16.3	72.1
Organic N = 45	6.7	15.6	78.8

*Includes manic-depressive depressed, involutional melancholia, and reactive depression.

Of the groups studied, the manics were closest to the normal distribution, while the other disorders were almost indistinguishable from one another on the basis of total score, although they were strikingly different from the norm. Perhaps of greater importance is the fact that the

[2]The range of "normality" for each item in the battery was individually determined by the percentile method, with the 80 per cent level acting as the "cutting-point." Which is to say that 80 per cent of the normal group reactions were within the determined range on a given item.

schizophrenics, depressions, and organic psychoses, which together comprise more than 75 per cent of the cases committed to mental hospitals, are positively identified here as psychotic 68.8, 72.1, and 78.8 per cent of the time respectively, on the basis of total test scores alone. (Of our total abnormal group, 58.5 per cent obtained scores within the abnormal (12–45) score range.)

Some aid in differential diagnosis can be obtained from comparison of the scores on the three scored tests[3] of the battery. The mean subtest scores and per cent of cases with subtest scores greater than 6, among some of the psychoses studied, are presented in Table II.

TABLE II

MEAN SUBTEST SCORES AND PER CENT OF CASES WITH EXTREME SUBTEST SCORE IN FINAL STANDARDIZATION GROUPS

Diagnosis	Word Association		Conformity Index		Multiple-Choice Rorschach	
	Mean	% > 6	Mean	% > 6	Mean	% > 6
"Normal"	1.31	3.0	.33	—	2.13	3.0
Mania	4.77	25.0	2.45	11.4	4.34	25.0
Schizophrenia	7.28	56.0	3.55	19.3	5.42	37.6
Depression	9.14	69.8	3.14	11.6	4.49	25.6
Organic	9.36	71.1	4.40	24.4	5.29	37.8

Whereas normals usually score higher on the Multiple-Choice Rorschach than on the Word Association Test, this pattern tends to be reversed among psychotics. We have often found, in cases where the score was high on the Multiple-Choice Rorschach but low on the Word Association Test, that the subject was relatively normal or recovering, though perhaps a potential psychotic. On the other hand, high scores on either the Word Association Test or the Conformity Index occur more frequently in severe mental disorders.

The normal subject scores low on all subtests but particularly low on the Conformity Index. Scores of more than 3 on this test were so scarce among normals, that we may safely say that if a record contains a score on the Conformity Index it should be viewed with suspicion. We have only once obtained a record from a normal subject with fewer than two common responses.

Manic individuals, contrary to what one might expect, do not have fast reaction times. Their distractability and flight of ideas prohibit a normally controlled word association. As their hyperactivity recedes to the hypomanic phase the reaction times become shorter.

[3]The modified Thematic Apperception Test, while generally included for qualitative assessment, was not found to be amenable to a simple objective numerical scoring system, and is therefore not involved in the total test scores of this battery.

Schizophrenics tend to have the highest Multiple-Choice Rorschach scores, and organics the highest Word Association and Conformity Index scores. Test scores in both types of disorder, however, are generally high, reflecting the severity of the personality disorder and the extensive thought disorganization in these illnesses.

The depressed individual, though having prolonged reaction times due to psychomotor retardation, can generally be distinguished by the relatively normal content of his word association.

Although we would assume that records obtained from psychoneurotic individuals would generally score midway between the normal and the psychotic, our experience has been limited to 26 cases, all relatively severe, and hence we are unable to draw conclusive inferences.

Other differential diagnostic signs on the basis of their empirical occurrence seem useful. These fall into the category of what might be termed clinical impressions. They are but "leads" and should be used with caution, since they have not been statistically validated.

One gains the impression that in manic states movement responses on the Multiple-Choice Rorschach are frequent and more than one colour response is likely. Rhyming, phrase completion, and verbal overproduction may occur on the Word Association Test, while euphoric expressions and plots are not uncommon in the T.A.T.

Inconsistent reaction times, particularly in conjunction with several irrelevant or bizarre associations and/or a low Conformity Index may be viewed as suggestive of schizophrenia. Card V of the Rorschach is sometimes rejected by these patients and they may occasionally give a pathological response to card III.

Not uncommon in the organic psychoses are long reaction times, failures in the Rorschach, an unproductive T.A.T. and/or perceptual difficulties manifested on picture 11. Typical, though not too frequent, is the occurrence of echolalia or verbigeration (word perseveration) during the Word Association Test.

Failures in the Rorschach are frequent in depression, and "black shock" to card V is often seen. While the content of the associations may be quite normal, deviations such as blocking or depressive content are most likely to occur on "river," "sickness," and "money." The reaction times are generally prolonged when retardation is present. An unproductive T.A.T. is fairly common, though depressive expressions and plots may occur. The mention of suicide in picture 14 may well be significant.

False Negatives

We have outlined above features common to the different diagnostic categories. However, examination of cases "not screened" leads to an appreciation of the limits of the total score. The false negatives (test

score 0–6) occurring in our "final" abnormal group (N = 350) were as follows:

7	cases	or	53.4	per cent	of the	alcoholic group
15	"	"	34.1	"	"	manic "
8	"	"	30.8	"	"	psychoneurotic group
9	"	"	26.5	"	"	not diagnosed "
13	"	"	11.9	"	"	schizophrenic "
5	"	"	11.6	"	"	depressed "
3	"	"	6.7	"	"	organic "

plus 12 cases of miscellaneous diagnoses.

Thus, a total of 72 abnormal cases or 20.6 per cent of our "final" abnormal group gave test results "within normal limits." Generally speaking, these were the less pathological cases. The percentage of false negatives per group shows that approximately one-half of the alcoholics, one-third of the manics (often tending to hypomanic reaction), and one-third of the psychoneurotics were not screened by the total test score. This agrees fairly well with the clinical findings. Most alcoholics recover from their psychotic episodes in a relatively brief period of time but are often not discharged until an enforced period of "freedom from alcohol" has been completed. Thus, it is not surprising that many such alcoholics will attain a score within normal limits. The psychoneurotics, of course, are by definition not psychotic and therefore as a group more likely to perform closer to the normal than those patients with psychotic disorders.

Most hypomanics and many of the less severe manics are often capable of an adequately sustained attention for a limited period of time during which they may well perform within normal limits. On the other hand, the false negatives are considerably fewer among the psychoses of greater severity, that is, among the schizophrenics, the organic psychoses, and the depressions, where the psychopathology is of more extensive and intensive pervasion. Among the schizophrenias and depressions, as might be expected, the paranoids and the reactive depressions, respectively, more frequently obtain a normal score.

The limitation of the total score is illustrated by the case of R. L. By giving mostly popular responses to the Multiple-Choice Rorschach he was able to gain a subtest score of 0. On the Word Association Test he gave two echolalias and three echolalias with verbigeration, but since his reaction time was fast he again escaped scoring. These responses were still evident on the Conformity Index, but he did manage to give three common responses and therefore attained only a total test score of 3. On the objective scoring he was within normal limits, but the qualitative deviations were so striking and pathognomonic on the association tests that he was thought to be suffering from an organic impair-

ment. Subsequent neurological examination revealed a brain lesion. While this is a striking example, many inferences of clinical value can be drawn from the qualitative nature of the responses, thereby extending the use of the battery beyond its already demonstrated capacity in quantified form.

Thus, it becomes evident that certain peculiarities may be noted within the normal score range, and that low scores generally, but not necessarily, indicate adequate adjustment.

The Individual Tests

Several generalizations of guiding value can be drawn concerning response on word association tests (2, 4, 5, 8). When the reaction time is quite specific and deviant from the usual it will in itself indicate an area of conflict and may even yield information concerning its nature. However, when the deviations are frequent, they are apt to be merely a reflection of a generalized disturbance of the association process. The individual should react with words conceptually related to the stimulus word; in fact, normals show a significant amount of inter-individual consistency in the route their associative processes take as demonstrated by the occurrence of common or popular responses. Marbe's law states that the more frequent (common) the response the shorter is the reaction time. The great frequency of coordinate (red–blue, pepper–salt) and contrast or opposite (hard–soft) responses is characteristic of adults.

The words selected for the Word Association Test in this battery have during their extensive use tended to bear out our original clinical expectations. "Table" was placed at the head of the list as it is generally innocuous. Response to "river" is frequently delayed in depressed persons, possibly because of implied suicide, while delayed response to "man" is often associated with sexual disturbances and is also found quite frequently in paranoids. Response to "food" is often delayed in depressed patients and frequently in schizophrenics or other persons with "oral" difficulties. "Pencil" was introduced as a comparatively neutral stimulus. "Voice" sometimes produces blocking in hallucinated persons, while "army" may be blocked because of its aggressive connotations. "Sickness" often reveals the patient's awareness of his own condition, producing, for instance, the response "doctor" or "despair" or "death." "Colour" is rather abstract and difficult and hence the response to it is frequently delayed. "White" or "red" are usually given by excitable patients while "brown," "black," and "blue" are depressive responses. "Money" again may bring out expansiveness or depressive trends ("gold," "buying," "dollars," or "none," "hunger," "debts").

Though many classifications have been proposed, attempts to classify all associations into a series of categories have generally been found to

be impractical. The references listed in the bibliography (2, 4, 5, 8), give a discussion of the value and shortcomings of these classifications and provide a more ample theoretical framework for the interpretation of word associations than can be presented here. In summary it can be said that the Word Association Test is a measure of the degree of mental control, yielding information on the nature of the thought processes.

The words in the Conformity Index were selected from the frequency tables of Kent and Rosanoff (2, 5) and were among those with responses of the highest frequency values, that is, "common" associations. An adequate number of common responses, four or more, reflects an average capacity to associate along common lines. Where common responses are rare, or absent, there is suggestion that the thought content may be unusual.

Since the subject generally writes his associations to words in the Conformity Index, graphological deviations, when they occur, may prove of interpretative value.

The Multiple-Choice Rorschach Test (1) was included in the battery as a measure of the personality structure. Interpretation broadly follows the established Rorschach pattern. Human movement responses (M) are said to reflect a capacity for constructive ideation. The selection of popular and frequently given responses of good form reveals an ability to perceive usual or common items, thereby lending an indication of the reality contact. Responses involving colour point to the nature of the affective expression of the subject. Pathological preoccupation with bodily functions may be detected through anatomical answers of poorly defined form. The presence of anxiety is seen in the X-ray and cloud responses. Failures may result from rejection or inability on the basis of perceptual distortions.

While we were unsuccessful in our attempt to mould the T.A.T. (6, 7) into an objectively rated test, it nonetheless has proved highly useful in an abbreviated form when interpreted in the usual manner. Generally, we have used pictures 5, 14, and 11 in this order. Picture 5 was chosen because it frequently brings out paranoid tendencies. It also contains a mother figure. Number 14, though generally eliciting the aspirations and day dreams of the subject, may evoke depressive or even suicidal inclinations, while number 11 was intended to bring out a response to an anxiety-provoking situation of symbolic nature.

It would appear that the more vague the content of the picture, the less often is a normal theme constructed, and the more frequent (among psychotics) the bizarre and incoherent productions become. Although these three pictures were intended to screen for common psychopathological symptoms, we would not hesitate to alter the selection in accordance with the subject being tested. The use of selected pictures of the

Thematic Apperception Test to elicit information concerning a specific or suspected conflict area has proved itself a valuable procedure. Experience in psychodynamic interpretation is, of course, a prerequisite to successful use of this technique.

Failures–Rejection

The incidence of failures (the choice of "nothing at all") is seen to vary on the Rorschach cards. It is often reported in the literature that cards IX and VI are commonly rejected even by some normals. In the multiple-choice test, card VI is failed by 10 per cent of normals while card IX is failed by 9 per cent of normals. None of the other cards are failed more frequently than 5 per cent of the time among a normal group.

Judging from the "Chi-square" values of the original standardization, rejection or pathological response on cards III, V, and/or X yields relatively stronger evidence of personality disturbance than aberration of response on the remaining cards.

While we might reasonably expect failures to be more frequent in a group of psychotic patients than in normals, as many authors have claimed, it is to be noted that in card VI and only in this card, the trend is reversed. Strikingly, card VI was more frequently failed by our normal than our abnormal groups. On the other hand, pathological responses given to this card by the patients tended to be "free-floating anxiety" responses. However, the "Chi-square" value for card VI is the lowest in the series and shows that between the normal and abnormal groups there is no difference of consequence in number of responses above the norm. It would appear from this that the type of psychological disturbance indicated by pathological response to card VI is not dependent on a psychosis. Thus, though this card tends to arouse anxiety in the patient, it is likely to be rejected by the normal, showing that the defence mechanisms in the normal are more effective.

A trend somewhat similar to this may be noted on picture 11 of the T.A.T. This picture is intended to bring out a response to an anxiety-provoking situation of symbolic nature. Of the three cards on which we have statistical data, the highest incidence of rejection occurred with picture 11, and this in the normal group; and in the abnormal group the card produced a sharp increase in the number of bizarre and incoherent stories. We must conclude that failure to give a response is less pathological than is a bizarre or incoherent response.

Failure in the Word Association Test, that is, blocking to a particular stimulus word, often indicated areas of psychopathology.

Intelligence and Age

The tests appear relatively independent of intelligence. Scrutiny of the records of our normal group did not reveal any significant test variations

referable to the intellectual level of the subjects. We must, however, admit to exceptions to this latter statement in cases of mental deficiency (although they can hardly be classed as normals). Mental defectives often receive an "abnormal" score, and it should be noted that differential diagnosis of these patients by the projective battery is apt to be quite inaccurate. They are, nevertheless, frequently screened out for further investigation.

Age was found to exert a limited influence on the test results. From the age of majority (21) to the involutional period (49) no appreciable age influence could be discerned. After 50 years of age, however, a trend of gradual and slight slowing of the reaction times could be noted. Though this had the effect of raising the scores on the Word Association Test somewhat, the other tests were apparently not influenced by aging and hence the rise in total test score was limited. It must be pointed out that we have an insufficient number of cases older than 65 to draw further conclusions. However, judging from Rorschach studies, the projective tests conform to, and reflect, the pattern of normal senescent decline as it has been established in the studies of age and intelligence.

SUMMARY

The clinical application of the Verdun Projective Battery has been outlined. Although it was designed as a quantitative screening device suitable for retesting and follow-up, qualitative deviations have proven of particular aid for the interpretation of psychopathology and for differential test diagnosis. Limitations of the battery are given consideration. The four projective tests comprising the battery have been modified into simple, brief procedures, three objectively scored and specifically adapted for the evaluation of psychotic disorders.

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EFFECT OF LENGTH OF SERIES UPON GENERALIZATION AND CENTRAL TENDENCY IN THE DISCRIMINATION OF A SERIES OF STIMULI

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IN A PREVIOUS PAPER (4), the effects of generalization and central tendency were studied in a graded series which was discriminated upon the basis of predominating colour. The resultant generalization curve was of a leptokurtic, slightly skewed frequency type, extending on both sides to the limits of the series. A pronounced central tendency was found; properly speaking, it was a series effect which seemed to compress O's responses towards two foci in the series, indicated by the distortion of the median response values. The compression of the responses towards two foci rather than a central one, as found by Hollingworth (1, 2), suggested that the judgmental processes involved might be a function of the length of the series. Since the original series was made up of 11 stimuli, and hence was a rather lengthy one, it seemed of interest to determine whether the same results would hold in a shorter series. The purpose of this paper, therefore, is to study the effects of generalization and central tendency in four series, composed of 6, 7, 9, and 11 stimuli respectively.

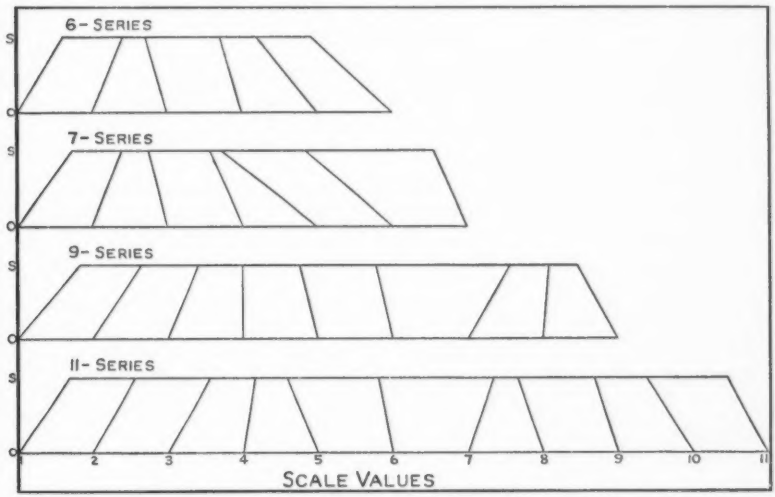

FIGURE 1. CENTRAL TENDENCY EFFECT
Subjective scale values (S) and objective scale values (O) are indicated for the different series. Note the tendency to compression of the scale values (foci) at points 2.5 for the 6- and 7-series, and at points 4 and 8 for the 7- and 11-series.

The same material and somewhat the same procedure as in the previous experiment were employed. The only change was that the times of presentation of the stimuli were slightly longer and that tachistoscopic presentation was not used. The task consisted of making an absolute judgment of the predominating colour on 11 cards, on each of which were 36 dots. The dots were either blue or green and the colours were randomly distributed. The maximum number of blue dots on any card was 23 so that the number of green dots on that card was 13; this was the 23–13 card. The next card in the series, 22–14, had 22 blue dots and 14 green ones. Thus, the series was formed by 11 cards, starting with 23 blue dots and going down to 13 dots of that colour, while the number of green dots on those cards increased progressively from 13 to 23. In this experiment, additional series consisting of 9, 7, and 6 cards respectively, were added. They all started with the 23–13 card and carried down as far as the 15–21 card for the 9-series, the 17–19 card for the 7-series, and the 18–18 card for the 6-series. A different colour combination was used for each series. All cards were presented individually in random order from behind a screen which shielded the experimenter. As each card was exposed, O had to determine the relative amount of a previously designated colour and locate on a scale (from 1 to 11 for the 11-card series) the point which, in his opinion, represented the relative amount of the designated colour. Hence, the psychometric procedure was that of the absolute judgment. No exposure was longer than two seconds, and the exposure terminated when O made his judgment. The four series were presented in counterbalanced order to four college women, who made 10 judgments on every card in each of three sessions. Thus, the results are based upon 120 judgments per card; there were 3,960 judgments in all.

Generalization gradients, determined according to the method described in the original paper (4), are presented in Table I. Both the forward gradient (F) and the backward gradient (B) are shown. The mean correct number of responses is shown in column C, and the mean number of responses displaced one, two, etc., positions away from the correct position are also indicated. It is seen that, in general, the judgments of the shorter series tend to be distributed closer to the correct position than those of the longer series. There is some tendency to skewness in all series. Regardless of the length of the series here studied, the generalization gradients, for the same approximate degree of learning, are roughly of the same form.

When the median responses for each scale position are computed (Table II), measures of the subjective values of the stimuli are obtained, which are prone to differ considerably from the objective value of the

TABLE I

GENERALIZATION GRADIENTS*

Series	Displacement							
	C	1	2	3	4	5	6	7
6F	39.3	26.8	13.5	4.3	.5	1.0		
6B		33.0	20.5	9.3	3.0	—		
7F	42.1	23.0	9.2	6.0	1.3	—		
7B		28.9	20.8	9.7	4.3	2.0	.5	
9F	37.1	29.5	17.9	6.4	3.6	1.0	—	.6
9B		22.2	14.4	6.2	1.7	—	—	—
11F	33.8	23.3	16.0	7.5	2.3	1.5	.2	.8
11B		21.5	15.6	7.7	4.9	1.8	1.8	.8

*This table lists the average number of judgments assigned to each position in terms of the displacement of that position from the correct position C.

stimuli. The discrepancy between the subjective values, as measured by the medians, and the objective values is shown in Figure 1 and is an indication of the central-tendency effect. It may be noted that in series 6 and 7, the median values tend to be compressed towards approximately value 2.5 on the objective scale. In the previous paper this point was called the focus. Series 9 and 11 seem to have two foci, around values 4 and 8 on the objective scale. Foci were found at these two points in the 11-series in the original experiment.

TABLE II

SCALE VALUES FOR SERIES OF VARYING LENGTHS

Positions	1	2	3	4	5	6	7	8	9	10	11
6-Series, 32.5 per cent correct											
Total	97	159	156	124	110	74					
Correct	55	40	34	30	35	40					
Per cent	56.7	25.2	21.8	24.2	31.8	54.1					
Median	1.61	2.40	2.71	3.72	4.22	4.96					
7-Series, 31.8 per cent correct											
Total	101	157	174	132	105	83	88				
Correct	51	46	38	28	23	28	53				
Per cent	50.5	29.3	21.8	21.2	21.9	33.7	60.2				
Median	1.73	2.39	2.76	3.58	3.76	4.87	6.65				
9-Series, 31.0 per cent correct											
Total	86	122	127	129	128	111	109	134	134		
Correct	49	40	34	28	24	22	26	47	65		
Per cent	57.0	32.7	26.8	21.7	18.7	19.6	24.2	35.0	48.4		
Median	1.82	2.61	3.39	3.98	4.75	5.78	7.53	8.04	8.43		
11-Series, 28.2 per cent correct											
Total	98	114	122	148	126	137	126	122	115	97	115
Correct	55	36	28	34	29	28	27	23	23	29	60
Per cent	56.1	31.6	22.9	22.8	23.0	20.4	21.4	18.8	20.0	29.9	58.2
Median	1.69	2.54	3.54	4.15	4.60	5.82	7.31	7.67	8.67	9.37	10.50

The finding that the shorter series have one focus, and the longer series, two foci, is of some interest. What has been called the central tendency implies that the subjective values tend to be compressed approximately toward the centre of the series. It seems that this statement should be modified for the longer series, in which case the subjective values are compressed towards two foci. The term series effect, which has sometimes been used, is therefore a better term than central tendency.

When the number of judgments at each point in the scale is not arbitrarily fixed, the term central tendency has another implication. In addition to a compression of scale values at focal points, there is a tendency for the judgments to be assigned more frequently to certain scale values. Just as, in the case of the shorter series, there is one focus, so also for these series there is one modal point, at which the number of judgments is a maximum; the longer series have two foci and two modal points.

Because each card was presented the same number of times, objectively there should be an equal number of judgments assigned to each scale point. Subjectively this is not so. Hence if one wishes to compute the accuracy of the judgment at each point of the scale, the proportion of correct judgments to the total number of judgments must be determined for each scale point; in other terms, the relative, rather than the absolute, accuracy is important. Curves based on the relative accuracy at each point on the scale are definitely U-shaped, or catenary-type curves.[1] Table II gives the data for computing the relative accuracy at each point from which the curves in Figure 2 were drawn.

When absolute judgments are attempted in a difficult series of judgments, errors, of course, occur. These errors, which are non-discriminated or generalized responses, diminish in frequency according as they deviate from the correct position. As aids in the formation of his judgments, O tends to use the end points of the series as standards or frames of reference. The accuracy of his judgments falls off exponentially as the stimuli deviate from each terminal stimulus, yielding a catenary curve of relative accuracy.

In a longer series, however, consisting of more than seven stimuli, judgments somewhat beyond the centre of the series become much more difficult. The sharpness of the terminal frames of reference is considerably diminished and O makes use of cues that are not primarily perceptive; he starts to rely upon some pseudo-probability theorizing of his own making. As a result, if the series is not greater than seven times in length, he is prone to assign more judgments near the centre of the

[1]The relative accuracy curve at each point in a 6-series, based upon a large number of judgments, very closely fitted a catenary curve (3).

series, which becomes the modal point. In a longer series, two modal points emerge, because O now assigns larger numbers of judgments to both sides of the central point. However, the increase in frequency of the judgments does not entail a consequent increase in relative accuracy at modal points, so that the curve of relative accuracy is still of the catenary type.

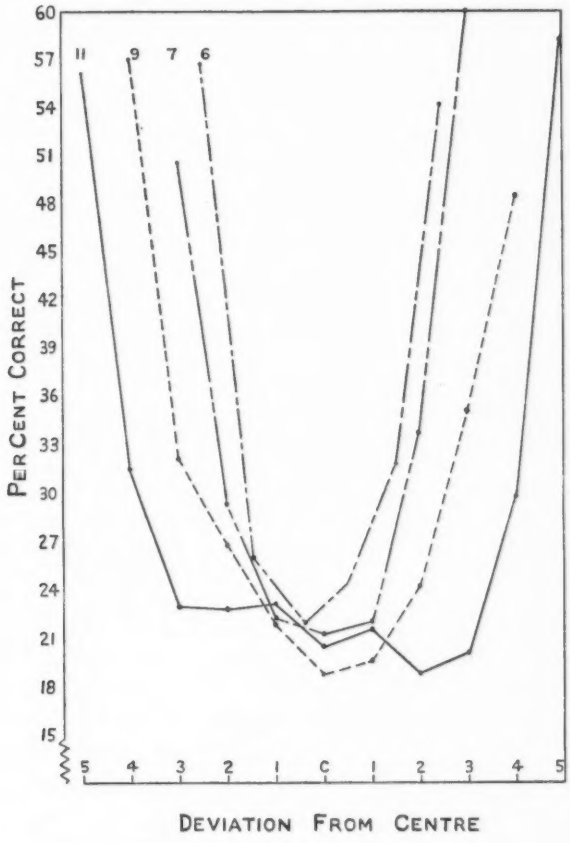

FIGURE 2. RELATIVE ACCURACY CURVES

Ordinates: Percentage of correct judgments of the total number yielded at any scale point. Abscissae: Deviations of positions from the centre of the series. Number of points in each series indicated by numeral at top left of each curve.

Since the judgments at the terminal points can be assigned in only one direction, the generalization curve for these points is truncated and, for points near the ends of the series, the generalization curve is truncated to a lesser degree. Hence, when the subjective values at each point in the scale are determined from the median values of the judgments, they tend to be compressed somewhat near the centre of the series so that a central focus is found in a short series. In a longer series the frames of reference are no longer confined to the extreme stimuli and the series tends to be split into two unequal parts for the judgment process. Two modal points and two foci emerge, because of the dwindling influence of the terminal frames of reference and the tendency to make use of a pseudo-probability theorizing in the assignment of judgments on both sides of the centre of the scale.

Thus, terminal frames of reference, generalization of error, utilization of subsidiary cues, and a pseudo-probability theorizing account for the formation of modes and foci and the catenary shape of the accuracy curves in serial discrimination.

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SOME EMOTIONAL PROBLEMS OF ORPHANAGE CHILDREN[1]

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THE TERM "orphanage children" is one that is too broad to leave unqualified. There are at least two distinct groups in an average orphanage population, children who were placed in infancy and children who were placed later when their homes were broken by the death or separation of parents. Since the former group were studied over a long period of time by William Goldfarb (2–8) and others, it is with the latter group that this study deals.

Subjects

The children in the study were all eight or nine years of age, and had spent at least the first five years at home. They were of normal intelligence or better. A control child from an intact home was matched with each child by age, Otis I.Q., and socio-economic level. There were 12 boys and 12 girls in each group. The orphanage children were drawn from all the orphanages in the city of Halifax and were all the children in them who fulfilled the requirements of age, intelligence, and early years at home. A very brief history was obtained for each child.

Procedure

After the groups were matched, each child was given the Children's Apperception Test (1). This is a projective test with the same rationale as the T.A.T., but with 10 animal pictures. All children co-operated to the extent of telling 10 stories, though productivity varied enormously. The 48 records were analysed under a number of specific headings, such as "adequacy of hero"; and group means were tested for significance. In addition, an over-all interpretation of each record was made to determine the child's main problem. It is impossible in this space to give detailed results, but a considerable number of group differences were statistically significant and many more approached significance. The ones to be discussed are those that appear to be most significant psychologically, while showing clear-cut group differences in addition.

Results and Discussion

Adequacy feelings were rated on a five-point scale. The orphanage children show much weaker feelings of adequacy than the controls, and twice as many of the former feel generally inadequate, whatever the situation. This lack of self-confidence is more noticeable among the girls of the group, who also show a lower aspiration level. The orphanage

[1]This paper, presented at the annual meeting of the Maritime Psychological Association (1951), is based on a thesis submitted in partial fulfilment of the requirements for the degree of Master of Arts at Dalhousie University.

CAN. JOUR. PSYCH., 6, 4 (1952).

children feel least adequate when under attack and when in conflict with parent figures, but this they share with the control group. However, their frequent feelings of inadequacy when alone or in certain social situations are rare among the control children.

There is a strong tendency for the orphanage children to show less aggression than the controls, the impression given being one of more repression rather than less hostility. Guilt over aggressive feelings and actions is less common in the control boys, more common in the orphanage boys, the reverse of what was true for the girls. Since the boys expressed more aggression than the girls, it may be that the girls have repressed more of both; but in any case, the orphanage boys certainly feel an overpowering burden of guilt over any hostile or aggressive feelings. In the reverse situation, as the target of aggressive acts, the orphanage children most often submit passively or resort to flight. They are unable to turn confidently to a protector as can so many of the control group. Their fantasies of loving, protecting care break down in the face of actual attack, and they feel that they stand alone.

Sex typing, so important to later heterosexual adjustment, appears to be less firm in the orphanages. More of these children are uncertain of the sex of their hero than in the control group, indicating some uncertainty as to their role. In addition, the orphanage girls use more male heroes than the control girls. Various other indications show that this is quite likely to happen in the more rigid and restricted atmosphere of the orphanage, but they do not show clearly why this should be so. It may be the result of confusion concerning the sex role, of dissatisfaction with the female role, or of a quite different factor, lowered creative ability taking the line of least linguistic resistance. Any of these explanations indicates a handicap for the orphanage girl.

Sibling rivalry is not a major problem in the lives of the orphanage children unless they have a sibling living at home. Even then it tends to be swallowed up in the greater conflict concerning the parents. Where it does occur, aggression is less frequent as a response and withdrawal more frequent than in the control group. The differences are not statistically significant, but the number of stories dealing with sibling rivalry were so few in the orphanage records that it is difficult to compare the responses adequately. However, the general tendency of the orphanage children was to give way passively before the rival.

Anxiety is high in both groups, but the orphanage children show more, and more intense, fears than do the controls. Physical harm or punishment arouses most anxiety in both groups; but the fear of deprivation and of disapproval, closely connected, together far outweigh it in the orphanage children. The fear of desertion is also present in most of the latter group. That these anxieties are so much more frequent than

fear of loss of love seems related to the common tendency to consider the parents jointly rather than individually. The two findings together suggest that many of the orphanage children have lost or have never acquired the concept of love as a personal relationship apart from its outward signs.

Guilt over wrongdoing of any sort, but particularly aggressive actions, is higher in the orphanage children than in the controls, especially when only the boys of each group are compared. Punishment is nearly always extrinsic; no idea of wrong being, or bringing, its own natural punishment occurs in most of the records. Far more of the offences in the orphanage records are only wrong to the child because of his inner conviction that he is guilty just by existing.

The children of the control group are, on the whole, influenced by reality in their attitudes to their parents; in the orphanage the reverse is true. While a minority express a preference for the parent who is active and responsible, two-thirds reject the attentive parent for one who is dead or has deserted them, building up a fantasy picture of that parent which makes acceptance of the remaining one still more difficult.

Summary

From the foregoing, and from a consideration of the children's dominant attitudes and main problems, it is possible to build up a composite picture of an orphanage child. While it is an exact portrait of none of the group, it bears a strong family resemblance to all but two.

The orphanage child, then, feels inadequate. He shows less desire for achievement and independence, and his mental efficiency is reduced below his natural abilities by this lack of initiative and by repression. He is passive or panicky under attack and shows less aggression himself, with more guilt over what does appear. He cannot deal constructively with rivalry. He is extremely anxious, especially over being deprived, deserted, or disapproved of. He has a strong tendency to escape into fantasy, and this makes him less able to adjust himself to his very real problems. He (or perhaps she) is rather confused over sex roles. He shows a marked lack of interpersonal warmth, often amounting to withdrawal. He wants a person on whom he can lean and who will supply his demands for material proofs of affection without too many reciprocal demands. Because of this need, and his fearfulness and anxiety, he is over-compliant. He does not know how to resist unwelcome demands; he must either give in or become aggressive, and usually he gives in. Occasionally this passive personality development is complicated by more malignant features, suspiciousness or masochism, or deepens into something very near depression.

The contrast with the control group is greatest in two areas: the

controls give as well as ask for affection; and they attempt more active solutions to their problems. Where unwholesome defences appear they are more like neurotic symptoms, especially compulsions, in contrast to the schizoid withdrawal of so many of the orphanage group.

Conclusions

Although this study is limited to 24 children in a narrow range of age and intelligence, it does indicate that children placed in an orphanage after their homes are broken are severely handicapped in their emotional and mental development. Further studies, using a wider range of age and intelligence levels, might contradict some of these findings; but many of them are so clear-cut that there seems little cause to consider them the results of faulty sampling, and good reason for supposing them to be true results of the life situations of these children.

The whole study underlines the need for foster homes to replace orphanages. But if, while these homes are still scarce, the orphanage could reorganize its standards sufficiently to approve initiative rather than docility and to avoid condemning the child rather than his actions, it would be less damaging to the children.

These children must bear more than institutional routine, however. They must sustain severe conflicts concerning their parents, and frequently guilt feelings over their resentment towards the parents. Play therapy at the Child Guidance Clinic in Halifax has, since this study was begun, helped one or two of the subjects in this regard. In the larger orphanages it should be possible to train one of the staff members to provide such therapy for more children than crowded clinics can handle. It is the writer's impression that nearly all the children in this study desperately need help in bearing their conflicting emotions with less damage to their personalities and to their present and future peace of mind.

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STUDIES IN SOMESTHESIS.[1] III. ROLE OF SOMATIC AREAS I AND II IN THE ACQUISITION OF ROUGHNESS DISCRIMINATION IN THE RAT[2]

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THIS EXPERIMENT is the third in the sequence of studies of the role of Woolsey's (2) somatic sensory areas I and II (SSI and SSII) in tactual discrimination. Earlier research (3) showed that removal of both SSI and SSII severely impaired roughness discrimination in the rat. All animals, however, were able to relearn the task but required approximately twice as many trials as they did preoperatively. Ablation of SSI produced greater impairment of retention than removal of SSII. These experiments raised a question regarding the possible importance of these somatic areas in the initial postoperative learning of a tactual problem. The present experiment was designed to throw light on this specific question.

PROCEDURE

Apparatus

The apparatus for training the rats in roughness discrimination consisted of a wooden box with external dimensions of 12 in. by 6 in. by 6 in. (Figure 1). Two L-shaped levers protruded through one end of the box. Each lever was covered by a detachable brass cylinder about ¼ in. in diameter. One half of each cylinder was made rough by covering it with wire gauze; the other half was left smooth. Two sets of such cylinders were used to provide two grades of roughness—one set with fine and the other with coarse wire gauze. By means of sliding keys the experimenter could rotate the cylinders, changing the upper surface from rough to smooth and vice versa. This device permitted the shifting of the rough and smooth surfaces from the left to right levers and back. The rats were trained to depress the rough cylinder. Electrical contacts were so arranged that depression of the correct (rough) lever activated an electrical feeding apparatus while depression of the incorrect (smooth) one resulted in shock. A foot switch was used to change shock and reward from side to side.

Operative Procedure

Fifty naive rats, all males, were used. At the start of the investigation they were approximately three months of age and averaged 220 gm. in

[1]"Studies in Somesthesis," Parts I and II, were published as articles in *The Journal of Comparative and Physiological Psychology*, vol. 44 (1951), pp. 339–53 and *Journal of Neurophysiology*, vol. 15 (1952), pp. 401–8.

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weight. One week prior to the brain operations all of the animals were peripherally blinded by enucleation. They were then divided into five groups and subjected to one of the following operations: (1) sham operation in which a midline incision of skin was made and two trephine holes were placed in the skull but no tissue was removed, (2) ablation of cerebral cortex both anterior and posterior to SSI and II, (3) ablation of SSI and II, (4) removal of SSI, and (5) removal of SSII. The operative procedure was as follows: In all operations pentobarbital sodium was

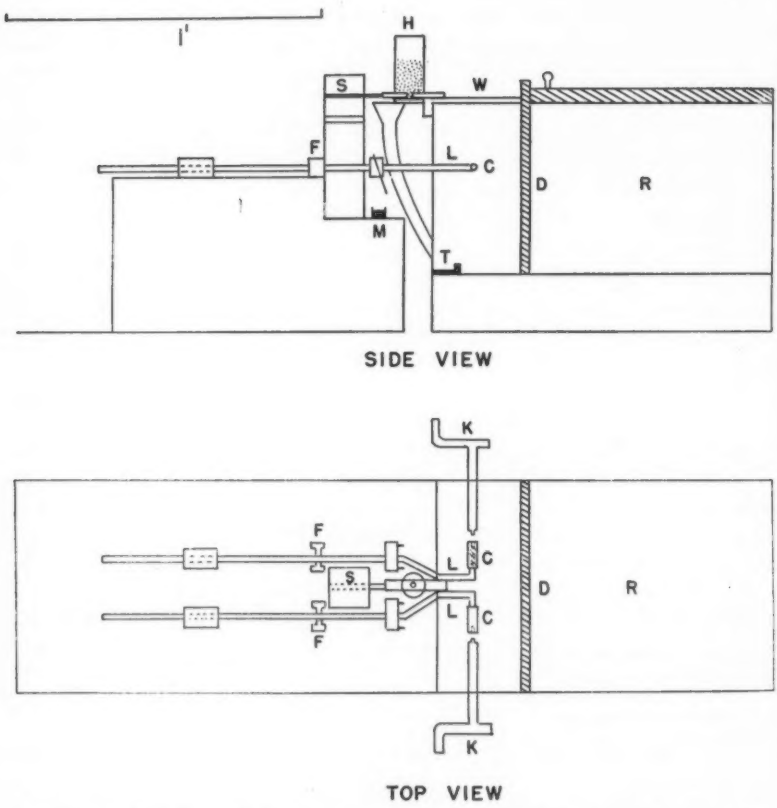

FIGURE 1. SCHEMATIC DIAGRAMS OF THE ROUGHNESS DISCRIMINATION APPARATUS

The most important features of the apparatus are: C, detachable cylinder; D, sliding door; F, fulcrum of lever; H, food hopper; K, sliding key for rotating cylinders; L, brass lever; M, mercury cup; R, restraining chamber; S, solenoid; T, food tray; W, glass window.

used as the anesthetic. Occasionally ether had to be used as a supplement. After incision of the skin and overlying fascia the bone over the desired area was removed and the cortical tissue removed by suction with a small glass pipette attached to an aspirator. At the conclusion of the operation the skin was sutured and the animals given a two-week recuperative period.

Postoperative Training

After the recuperative period the animals were put on a feeding schedule and following a week of this were habituated to the apparatus and trained to eat in it. They were then given access to one of the levers at a time and were taught to depress the levers to secure food. When the rats had completed this preliminary phase, the formal training to choose the rough rather than the smooth surface was started. The correct stimulus was alternated from side to side according to the Gellerman (1) sequence. Shock was not given for incorrect responses until the third day of training. During this initial discriminative training, the cylinders with coarse wire gauze were used. Each animal was given ten trials per day until a criterion of at least 90 per cent correct responses on two successive days was met. Following this relatively coarse discrimination, the cylinders with fine wire gauze were introduced, and training was continued until the criterion was met again.

Post-mortem Procedures

Upon conclusion of the discriminative training, the brains of all operated animals were fixed by a formalin perfusion technique. The brains were then removed, embedded, sectioned, and stained. The lesions were plotted on the conventional Lashley diagrams.

Results

Anatomical reconstructions of the brains are shown in Plates 1, 2, and 3. The behavioural results are summarized in Tables I and II. All scores shown in the two tables exclude criterial trials. Although both trials and errors are listed, only error scores are used in the calculations for tests of significance, since errors are generally considered to be better measures of learning than are numbers of trials. In the discussion to follow, Grade 1 discrimination refers to performance on the coarse grade of roughness and Grade 2 on the fine grade.

Sham-Operates and Animals with Anterior-Posterior Lesions

Table I records the number of trials and errors made by sham-operated animals and animals with lesions to the anterior and posterior regions of the cortex in the initial learning of the rough-smooth discrimination prob-

TABLE I

NUMBER OF TRIALS AND ERRORS REQUIRED TO MEET LEARNING CRITERION ON COARSE (GRADE 1) AND FINE (GRADE 2) ROUGH-SMOOTH DISCRIMINATION AFTER VARIOUS OPERATIONS

ANTERIOR-POSTERIOR LESIONS					SHAM-OPERATES					SOMATIC I + II LESIONS				
	Grade 1		Grade 2			Grade 1		Grade 2			Grade 1		Grade 2	
Rat No.	Trials	Errors	Trials	Errors	Rat No.	Trials	Errors	Trials	Errors	Rat No.	Trials	Errors	Trials	Errors
10	70	24	0	0	2	110	47	10	2	0	340	130	60	22
11	200	101	10	2	3	60	27	0	0	1	310	126	110	31
12	150	61	40	12	4	160	61	10	2	6	190	89	100	36
13	160	62	10	2	5	190	73	20	5	24	360	172	10	4
14	140	58	10	3	8	150	51	20	5	25	180	68	20	8
16	100	38	10	2	9	100	35	10	2	26	315	144	40	14
17	170	78	20	8	19	200	84	10	2	34	270	97	50	12
20	120	43	30	8	23	150	63	0	0	37	290	112	40	13
21	50	20	10	4						40	120	33	0	0
										44	300	127	50	15
										49	184	82	20	4
										15	–	–	–	–
										18	–	–	–	–
Mean	128.9	53.9	15.6	4.56		140	55.1	10	2.25		259.9	107.3	45.5	14.5
S.D.		24.4		3.68			17.8		1.78			36.9		10.7

lems. Both groups made approximately the same number of errors in learning to discriminate the coarsest cylinder from the smooth ($P > .90$) as well as the fine discrimination ($P = .10$). We may therefore conclude that removal of cortical tissue anterior and posterior to SSI and II does not affect the rate of learning of either coarse or fine rough-smooth problems. The lack of effect is interesting since all of the A-P (anterior-posterior) lesions invaded to one degree or another parts of SSI (see Plate 1). This suggests that small partial ablations of SSI have no deleterious effect on the learning of the particular tactual tasks studied.

TABLE II

NUMBER OF TRIALS AND ERRORS REQUIRED TO MEET LEARNING CRITERION ON COARSE (GRADE 1) AND FINE (GRADE 2) ROUGH-SMOOTH DISCRIMINATION AFTER ABLATION OF SPECIFIED CORTICAL AREAS

SOMATIC II LESIONS					SOMATIC I LESIONS				
	Grade 1		Grade 2			Grade 1		Grade 2	
Rat No.	Trials	Errors	Trials	Errors	Rat No.	Trials	Errors	Trials	Errors
29	230	99	30	12	27	330	142	20	5
31	140	54	10	3	28	320	152	30	11
35	130	59	20	7	32	373	142	50	17
36	240	90	60	18	39	210	85	70	26
38	210	77	60	20	45	290	122	30	12
41	200	73	94	34	33	—	—	—	—
42	180	71	80	19					
46	270	125	0	0					
47	180	72	0	0					
50	63	25	20	2					
Mean	184 3	74.5	37.4	11.5		304.6	128.6	40	14.2
S.D.		25.5		10.6			23.9		7.0

Animals with SSI + II Lesions

The performance of 13 animals with SSI + II removed is also shown in Table I. Examination of Plates 1 and 2 indicates that in most cases SSI + II were incompletely ablated. In the majority of these cases the face area of SSI lying near the rhinal fissure was missed owing to the relative inaccessibility of this region. This omission may not be too serious since few evoked potentials were recorded in the vicinity of this fissure. Inspection of Table I shows that animals 15 and 18 failed to learn the roughness discrimination (given 500 trials). Histological examination of the brains revealed no invasion of subcortical structures which might account for the lack of learning. The remaining animals

learned the discrimination with varying degrees of difficulty. Considering the performance of the 11 animals as a group, we note that they made roughly twice as many errors on the Grade 1 discrimination as either the A-P animals ($P < .01$) or the sham-operates ($P < .01$) and also more errors before meeting criterion on Grade 2 than either the A-P animals ($P = .02$) or the sham-operates ($P < .01$). On the basis of individual performance, a number of SSI and II animals, Nos. 25, 40, and 49, learned Grade 1 and 2 discriminations much more quickly than many of the A-P or sham-operated rats. Lesion locus or size cannot account for the differences. From the performance of the group as a whole it is clear that removal of SSI + II markedly reduces the rate of learning of both coarse and fine roughness discrimination. This reduction is not due to the sheer mass of the lesion, since it has been demonstrated previously that removal of large areas of cortex outside of SSI and II has no effect on the learning rate.

Animals with SSII Lesions

Table II lists the learning scores of animals subjected to removal of SSII. Comparison of the over-all mean performance of these animals with the first two groups of Table I shows that they made more errors on Grade 1 discrimination than either A-P animals ($P = .10$) or sham-operates ($P = .10$), and also that they made more errors on Grade 2 discrimination than either the A-P group ($P = .08$) or sham-operates ($P = .05$). None of these differences, however, are statistically significant, perhaps because in a number of the animals (Nos. 31, 35, 46, and 47) the lesions did not destroy all of the SSII tissue. These animals with partial ablation of SSII made fewer errors for both grades 1 and 2 than did the remainder of the group where SSII had been completely or almost completely removed; the small number of cases, however, precludes any statistically valid comparison of the relative effects of partial and total SSII removal. Further comparison of the SSII and SSI and II groups shows that the SSII animals scored significantly lower on coarse discrimination than did the SSI and II ($P = .04$), but did not score lower on fine discrimination ($P = .55$).

Animals with SSI Lesions

Unfortunately several of the rats in this group were lost during the course of the experiment and data are available for only six. One animal, No. 33, showed no signs of learning discrimination after 500 trials, when training was discontinued. No invasion of the subcortical tissues appeared which might account for this failure. Error scores of the remaining SSI rats were significantly greater than scores of either A-P or sham-operated animals on both grades 1 and 2 (P's $> .01 < .05$). Comparison of the

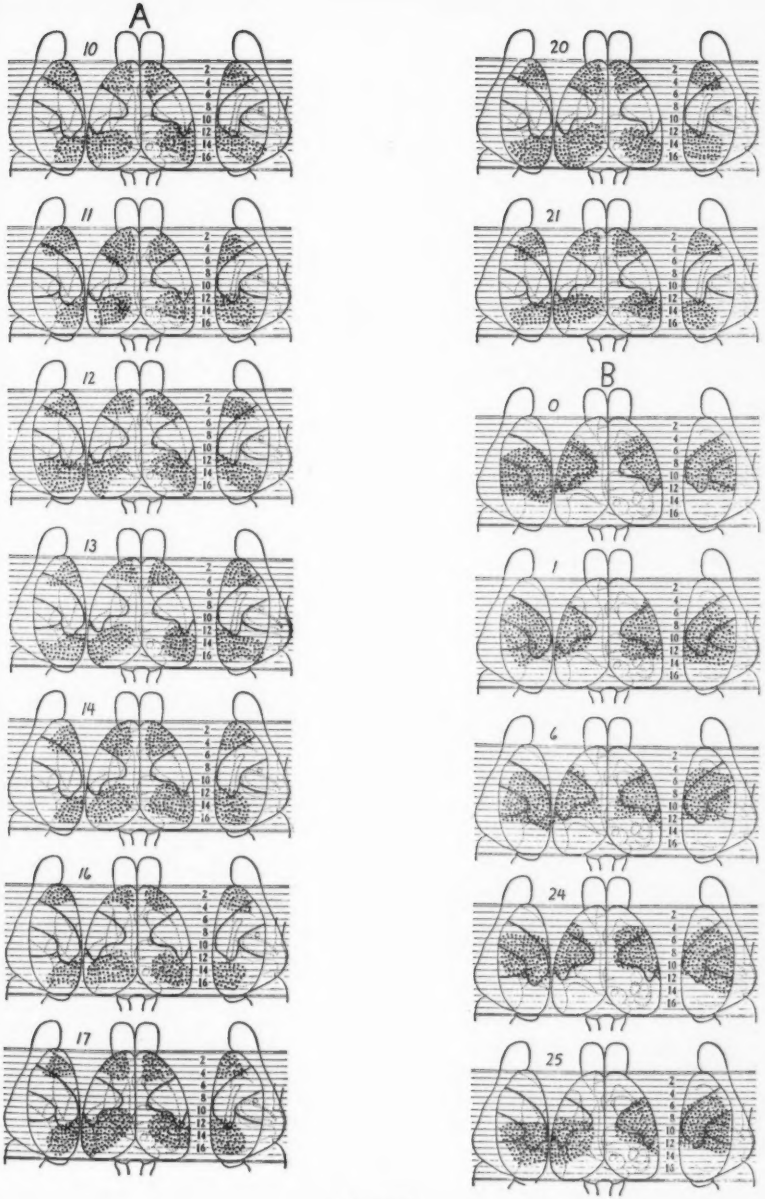

PLATE 1

The animal's experimental number is shown on the left of each diagram. The stippled area indicates the locus and extent of cortical destruction, and the heavy lines show the location of somatic sensory areas I and II. Group A: animals with anterior-posterior lesions; Group B: animals with SSI + II lesions; Group C: animals with lesions of SSII; Group D: animals with lesions of SSI.

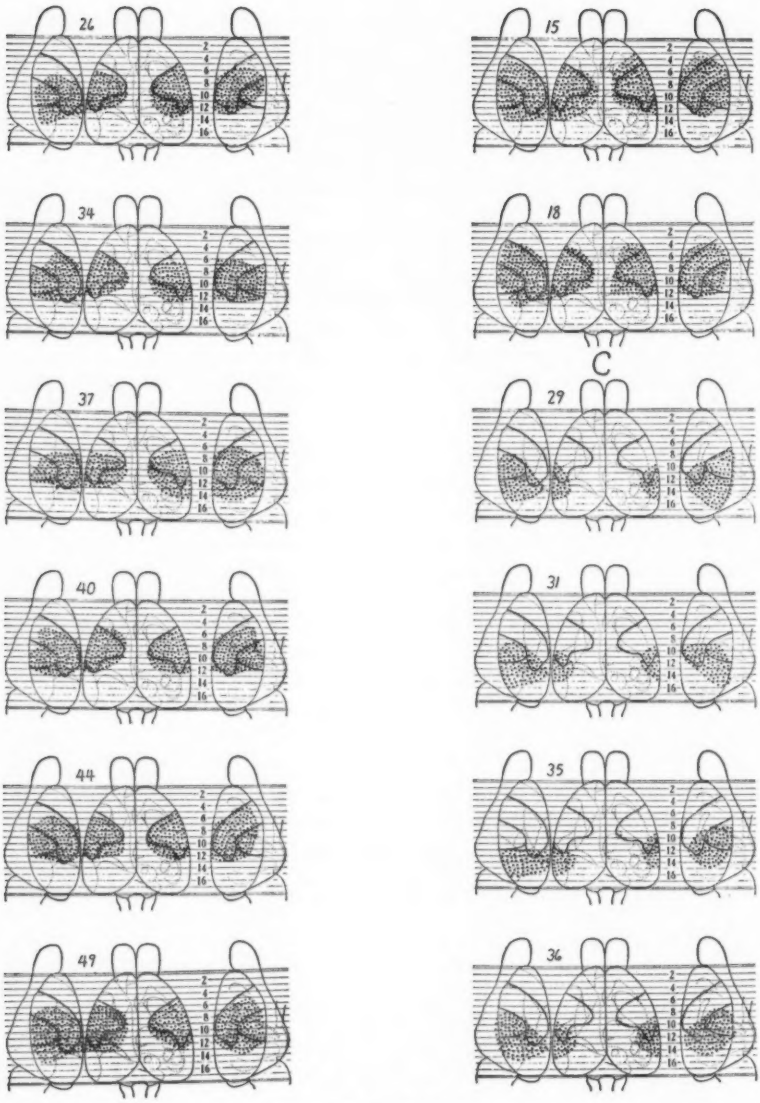

PLATE 2

The animal's experimental number is shown on the left of each diagram. The stippled area indicates the locus and extent of cortical destruction, and the heavy lines show the location of somatic sensory areas I and II. Group A: animals with anterior-posterior lesions; Group B: animals with SSI + II lesions; Group C: animals with lesions of SSII; Group D: animals with lesions of SSI.

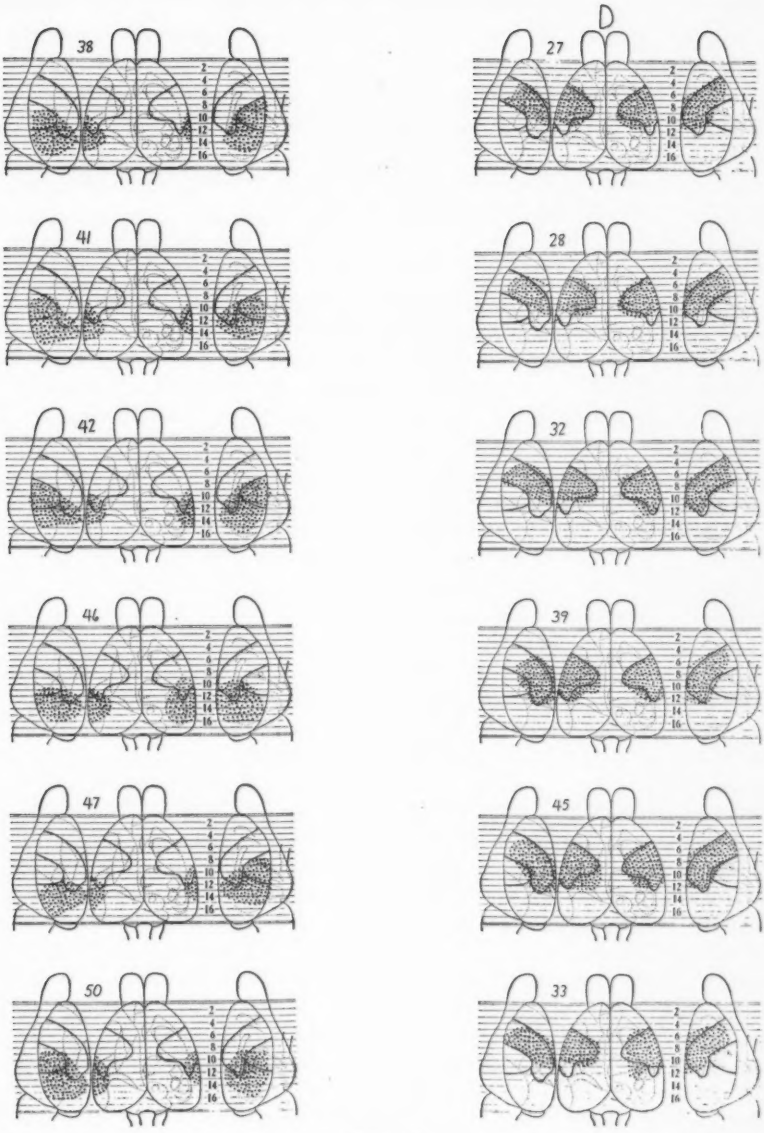

PLATE 3

The animal's experimental number is shown on the left of each diagram. The stippled area indicates the locus and extent of cortical destruction, and the heavy lines show the location of somatic sensory areas I and II. Group A: animals with anterior-posterior lesions; Group B: animals with SSI + II lesions; Group C: animals with lesions of SSII; Group D: animals with lesions of SSI.

performance of the SSI group with the SSI and II shows no significant difference in error scores on Grade I ($P = .25$) or on Grade 2 discrimination ($P > .90$). Finally, comparison of learning performances of SSI and SSII groups indicates that SSI animals made a significantly greater number of errors in learning Grade 1 discrimination than did SSII rats ($P < .01$). No significant difference was obtained between the two groups on Grade 2 discrimination ($P = .60$).

Discussion

The purpose of the present investigation was to study the role of somatic sensory areas I and II, together and separately, in the initial postoperative learning of a tactual task, coarse and fine rough-smooth discrimination. The results clearly indicate that somatic areas I and II play an important role in the initial learning of both grades of roughness discrimination, since removal of SSI and II significantly retards the rate of learning of tactual problems while ablation of equally large or even larger cortical areas outside the somatic region has no effect on such discrimination. If anything, animals with extra-somatic lesions tend to do better—though not significantly better—on the problems than sham-operated controls. This rules out the possibility that retardation was due to sheer mass of the cortical lesion.

Examination of the individual contributions of somatic areas I and II shows that they do not contribute equally to the learning of roughness discrimination but that area I is of much greater importance. Ablation of SSI alone produces as much retardation in both coarse and fine discrimination as does removal of the entire somatic region. On the other hand, the effect of ablation of SSII alone is not significantly different from the effect of the extra-somatic or sham-operations. This latter finding must be qualified in part since many of the cases included subtotal lesions of somatic II. It appears, therefore, that lesions of SSI have the greatest retarding effect on the rate of learning roughness discrimination, while lesions of SSII exert little, if any, effect. That learning still occurred in the absence of the entire somesthetic cortex indicates that it was mediated either by the remaining cortex or more probably by centres at the subcortical level.

These findings are, in general, the same as results of the earlier retention study (3). Removal of SSI and II severely impaired the retention of roughness discrimination, with SSI exerting greater effect than SSII. Little, if any, disturbance of retention occurred with extra-somatic lesions. In the present study on initial postoperative learning, the findings on retardation of learning resulting from various cortical extirpations are essentially in line with the earlier observations on retention.

SUMMARY

Fifty rats were peripherally blinded and then divided into a number of groups and subjected to ablations of the following areas: somatic areas I and II, somatic area I, somatic area II and cortex both anterior and posterior to somatic areas I and II. One group of animals was subjected to a sham-operation. All ablations were bilateral. After a 14-day recuperative period the animals were placed in a lever-pressing discrimination apparatus and trained to discriminate a rough (coarse grade) from a smooth cylinder. Following this learning they were introduced to a finer grade of roughness and trained to discriminate this from a smooth cylinder. Forty-six rats completed the experiment. The main findings are:

1. Animals subjected to removal of somatic areas I and II show a significantly lower rate of learning roughness discriminations (both coarse and fine) than do animals with large extra-somatic lesions or animals with sham-operations.
2. Removal of somatic area I alone produces as much retardation in the learning of both coarse and fine discriminations as does removal of the entire somesthetic cortex.
3. Lesions of somatic area II have little effect on the rate of learning of roughness discriminations.

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